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January 25, 1995

William F. Caton
Acting Secretary
Federal Communications Commission
1919 M Street, N.W., Room 222
Washington, D.C. 20554
STOP CODE: 1170

Re: Ex Parte Communication
PR Docket No. 93-61
Automatic Vehicle Monitoring

Dear Mr. Caton:

In an *ex parte* submission dated January 17, 1995, Dr. Jay E. Padgett, representing the cordless telephone industry, urges the Commission to prohibit the use of wideband forward links by wide-area automatic vehicle monitoring ("AVM") systems.[1] In his letter, Dr. Padgett echoes comments made in his earlier filings against the wideband forward link: his November 30, 1994 response ("*Padgett Response*") to my letter of September 15, 1994 ("*September 15 Letter*") and an August 8, 1994, *ex parte*.[2] I had written the *September 15 Letter* to clear up some misconceptions about the Pinpoint system and its bandwidth requirements that had arisen in the record in this proceeding in several parties' submissions, including but not limited to, Dr. Padgett's.

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[1] Letter from J.E. Padgett, Chairman, Consumer Radio Section, Telecommunications Industry Association ("TIA"), to Wm. F. Caton, Secretary, FCC, dated January 17, 1995.

[2] J.E. Padgett, "Wide-Area Pulse-Ranging AVM/LMS: Messaging Locating System Design Tradeoffs and Part 15 Interference," filed in PR Docket No. 93-61 on August 8, 1994 ("Padgett Papers"), as an attachment to an *ex parte* submitted by the Telecommunications Industry Association ("TIA").

In addition to Dr. Padgett's recent *ex parte*, Southwestern Bell Mobile Systems, Inc., ("SWBMS") responded on January 19, 1995 to an *ex parte* submitted by Airtouch Teletrac.[3] In its response, SWBMS argued that there are minimal performance benefits to be gained by wide-area AVM systems by using wider bandwidths (*i.e.*, ~ 8 MHz), relying in part upon Dr. Padgett's submissions as well as a report from Virginia Tech sponsored by SWBMS.[4]

This letter is submitted to make a few brief remarks in reply to these submissions of Dr. Padgett and SWBMS/Virginia Tech.

Bandwidth and Ranging and Location Accuracy

As Dr. Padgett acknowledges, return link bandwidths of 8 to 16 MHz provide better ranging accuracy in the presence of multipath than smaller bandwidths (*Padgett Response* at 5). In another paper recently filed in this proceeding, Dr. Costas N. Georghiades of Texas A&M University confirms that 8-10 MHz bandwidth systems demonstrate markedly improved performance over narrowband (1-2 MHz) systems in the severe multipath environments of urban areas.[5] Dr. Georghiades notes that these improvements affect location accuracy, data capacity and, as a result, location capacity, as stated in my *September 15 Letter*. Specifically, 8-10 MHz systems are better able to overcome Rayleigh fading and resolve multipath delays in the range of 100 ns (or less). This capability confers significant benefits on AVM systems in terms of improved detection of both data and the leading edges of multipath components, which is critical to highly accurate vehicle location. By contrast, the recent paper prepared by Virginia Tech merely observes that a 1.25 MHz system can resolve multipath to on the order of 5 to 7 μs as represented by their simplistic two-ray model. (See Georghiades Paper at 4, for a more complete discussion of the deficiencies of Virginia Tech model.) Wide-area AVM systems that

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[3] Letter from Louis Gurman, Counsel for SWBMS, to Wm. F. Caton, Secretary, FCC, dated January 19, 1995.

[4] "Final Report" of the Mobile and Portable Radio Research Group of the Electrical Engineering Department at Virginia Tech: "Capacity and Interference Resistance of Spread-Spectrum Automatic Vehicle Monitoring Systems in the 902-928 MHz ISM Band," filed in PR Docket No. 93-61, on October 19, 1994.

[5] C.N. Georghiades, "On the Effect of Bandwidth on the Performance of AVM Systems Operating in the 902-928 MHz ISM Band," filed in PR Docket No. 93-61, on December 7, 1994.

present only this level of resolution would often suffer errors in location estimates on the order of a thousand feet or more in urban areas, which is clearly unacceptable.

Bandwidth and Location Capacity

Dr. Padgett also states in his *Response* that if AVM system designers are not constrained from increasing the receiver carrier-to-noise ratio, location capacity can increase as the square of the increase in bandwidth (*Padgett Response* at 5-6). However, as Dr. Georghiades demonstrates on page 7 of his paper, for "*the same power and mean-square error performance*" there is "a quadratic increase in the location rate with bandwidth." (emphasis in original) By failing to account for the possibility of holding mean-square error performance constant, Dr. Padgett apparently overlooked this relationship between bandwidth and location capacity.[6]

It is important to note that the design philosophy underlying Dr. Padgett's discussion is at odds with sound engineering practice. He posits that systems will be designed to operate at threshold. In reality, AVM developers design their systems with margins to accommodate reasonable levels of interference as well as the vagaries of 900 MHz propagation. Under these circumstances, the relationship between location capacity and bandwidth is as I have described it above.[7]

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[6] As noted earlier, multipath resolution increases dramatically as one moves from 1 MHz to 10 MHz. Dr. Padgett agrees with Pinpoint that multipath is the main consideration in assessing ranging, and thus location, accuracy. Because mean-square error performance -- as opposed to multipath resolving abilities -- is already adequate at about 2 MHz bandwidth, there is little design tradeoff by holding this performance parameter constant as one moves to 8 MHz to improve location capacity, multipath resolution, and location accuracy.

[7] Southwestern Bell contends that the improvement in location capacity is only slightly better than the linear increase in bandwidth, primarily due to the need for "guardtimes," which I understand to be propagation times. In my *September 15 Letter*, I acknowledged that propagation times could affect the degree of the increase in location capacity with bandwidth *if* propagation times were of the same order of magnitude as pulse duration. In this regard, I would point out that the duration of the location pulse in the SWBMS Quiktrak system, slightly greater than one-quarter of a second, is *one thousand* times greater than the time needed for radio waves to propagate 50 miles (approx. 270 microseconds). Thus, increases in bandwidth beyond SWBMS's 2 MHz are likely to yield approximately geometric increases in location capacity. By way of comparison, Pinpoint's ARRAY™ system (1500-3000 locations per second)

(continued...)

Using Narrowband Forward Link Channels to Support Pinpoint's Location and Data Capacity

Dr. Padgett similarly ignores entirely the deleterious affects of Rayleigh fading on data capacity (and, as a result, location capacity as well) when suggesting that a single 500 kHz channel could meet the data and location needs served by the wideband forward link in Pinpoint's current design. While he criticizes the narrowband forward link solutions detailed in my *September 15 Letter* as "sub-optimal," he fails to understand that these solutions -- while decidedly inferior to Pinpoint's proposed wideband forward link -- were established to have the same practical (not just theoretical, as the *Padgett Response* assumes) capacity as the wideband forward link. With the wideband forward link, Rayleigh fading is effectively overcome. With a narrowband forward link, however, such fading presents a serious problem, and steps must be taken beyond achieving the same peak throughput to keep system performance at desirable levels.

More specifically, Dr. Padgett has suggested to Pinpoint that the GSM data standard will allow it to achieve the necessary data rates with only a few hundred kHz. On a 200 kHz channel operating under the GSM standard, there are under 100 kbps of usable data.[8] Thus, to match Pinpoint's current forward link capacity of 360 kbps,[9] four such channels would be needed *before* accounting for Rayleigh fading, which itself would reduce effective capacity by as much as 50%.[10] Accordingly, to offset these effects, as many as eight (8) 200 kHz

[7](...continued)
has a location capacity 13-27 times greater than the maximum capacity estimate recently claimed (for the first time) for Quiktrak (111 locations per second or 400,000 per hour).

[8] The raw symbol rate of a 200 kHz channel under the GSM standard is 273 kbps. When this channel is rate-one-half encoded to account for intersymbol interference, the effective rate is cut by 50 percent. Once additional steps are taken to achieve adequate performance, namely synchronization coding and training sequences, the effective throughput is approximately 96 kbps.

[9] The current data capacity of the 8 MHz wideband forward link is 360 kbps, which gives Pinpoint much more data capacity than the example Dr. Padgett cited from the *September 15 Letter*, where 500 vehicles were being located, 85 of which included a 2400 bit message. (*Padgett Response* at 7). I had used the example for illustrative purposes only.

[10] *See* Qualcomm Incorporated, "DCMA vs. GSM: A Comparison of Six C's of Wireless Communications" (80-12589-1, rev. x.1, 1994).

narrowband channels (1.6 MHz) would be needed to support the ARRAY™ system requirements.

Another way to overcome Rayleigh fading and avoid the signal acquisition problems associated therewith if narrowband links are used, as discussed in the *September 15 Letter*, would be to keep the base stations on continuously. Because Pinpoint's design requires all base stations to be capable of polling and communicating with vehicles, I posited a cell-reuse scheme in my *September 15 Letter* to avoid intrasystem interference. In order for this to be a robust scheme, the channels would have to utilize error correction coding and interleaving in order to minimize the effects of Rayleigh fading. Thus, for Pinpoint to maintain its high location and effective data capacity, the equivalent of several 500 kHz base station channels would have to be dedicated to Pinpoint for forward link functions (at least two in each "cell" of the reuse scheme), *in addition to the spectrum for the wideband reverse link.*[11] Notably, in this scenario, unlike the wideband forward link, the narrowband forward link channels could *not* be time shared unless the same facilities are used by all licensees.[12] Thus, for the very high capacities Pinpoint seeks to provide to meet IVHS applications in large metropolitan areas, and for the introduction of robust competition through time sharing, a wideband forward link is the operationally optimal and most spectrally efficient option.

Overstating the Interference Potential of the Wideband Forward Link

When Dr. Padgett turns his attention to potential interference from wideband forward links to Part 15 systems, he grossly mischaracterizes Pinpoint's system and overstates its interference potential. As explained in my *September 15 Letter*, and as Pinpoint has explained to Dr. Padgett at meetings to discuss AVM/Part 15 testing, the 1.0% average base station transmit duty factor that he cites (*Padgett Response* at 9) is during *peak capacity periods assuming full loading*. For most periods during the day, for *fully loaded* systems, the transmit duty factor of each base station will be a fraction of 1.0%, on the order of zero to 0.5%. Until systems are fully loaded, the upper range of transmit duty factors will be lower still.

[11] Note that one 500 kHz channel in each "cell" theoretically would give Pinpoint only about 70% of the capacity it currently enjoys (250 kbps/360 kbps).

[12] Ironically, such an arrangement would require uniformity of systems among different licensees to a significant degree, a result that Pinpoint aggressively sought to avoid when it proposed sharing. As Pinpoint has explained, wideband wide-area AVM channel could be accomplished simply by an agreed upon access protocol and a timing standard, requirements that leave designers considerable flexibility on both return and forward links.

Accordingly, on page 10 of his *Response*, Dr. Padgett grossly overstates the potential number of slots used by the average base station *during typical off-peak operation*, and this materially exaggerates the interference Part 15 systems might receive.

Dr. Padgett also overstates his case by all but ignoring a method of base station transmission Pinpoint can use to allow Part 15 frequency hopping spread spectrum systems to better detect the wideband forward link. I am speaking of aggregating each base station's transmissions so as to transmit on concatenated group slots. When Dr. Padgett was informed of this approach by Pinpoint in a meeting to discuss Part 15/AVM interference testing parameters last October, he immediately acknowledged that such aggregation would help frequency hoppers considerably in detecting the wideband forward links.[13] Tellingly, Dr. Padgett subsequently declined to participate in field tests to ascertain the degree to which the wideband forward link is really a problem. Pinpoint continues to believe that the best way to shed light on these and other contentious AVM/Part 15 compatibility issues is to conduct field tests.

Instead of participating in tests, Dr. Padgett offered his "Collision Analysis for Frequency Hopping Cordless Telephones with Adaptive Hopping Sequences," ("*Hopping Telephones*") with the *Padgett Response*. By itself, *Hopping Telephones* is largely irrelevant, as it fails to take into account the following major factors of which Dr. Padgett is or should be aware, almost all of which would have been accounted for in testing:

- "propagation path loss" and other "such 'real-world' effects" (*see Hopping Telephones* at 28), for example, near-far phenomena. In other words, all base station transmissions were assumed by Dr. Padgett to cause interference, a grossly simplistic assumption;

- the fact that the duty factors Dr. Padgett assumed for the Pinpoint base stations are not average over the course of a day but represent average *peak capacity on a fully loaded system*. Actual *average* individual base station duty factors on a *fully*

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[13] In an Attachment hereto, I describe possible conditions on the operation of wideband forward links by which (i) transmissions would be aggregated and (ii) *maximum* transmit duty factors of individual base stations would be limited. Pinpoint first formally proposed these restrictions in a December 13, 1994 letter from Patrick Bromley, Chairman of Pinpoint, to Commissioner Susan Ness. Another obvious way for cordless phones to minimize the interference they receive is to design the phones to avoid wide-area AVM channels until, if ever, the non-wide-area AVM frequencies are "saturated."

loaded system are expected to be as much as an order of magnitude *less* than the values Dr. Padgett used, and even less than that *before* systems are fully loaded;

- the ability (and intent) of Pinpoint to aggregate individual base station transmissions to fill multiple consecutive time slots allowing their presence to be more easily detected, as discussed in the Attachment;

- the statistical probability that at any one time five or more telephones would operate "within the same room" as another telephone (*see Hopping Telephones* at 2) at a sufficient distance from the cordless telephones' base units so as to be degraded; and

- the availability of proven methods by which the AT&T cordless telephones could be designed to virtually eliminate the interference described, such as adding more parity bits in the phones' coding and interleaving the data. These methods, which have been used in the land mobile community for two decades, are well understood and should have only a marginal effect on the phones' costs. Indeed, given the obligation of Part 15 designers to accept interference received, it should be incumbent for the phone designers to utilize such sound engineering before proposing the redesign of licensed systems, as Dr. Padgett seems only too willing to do. In fact, it appears that the only interference that the phones Dr. Padgett describes were designed to combat was interference between themselves.

When these factors are taken in combination, it is very likely that the mitigating effect on Dr. Padgett's theoretical results will be highly significant if not complete.

Further, by relying on the artificial scenario of all phones beginning operation simultaneously, *Hopping Telephones* is incomplete because Dr. Padgett does not also address the more realistic situation where additional phones are added to or reintroduced to the environment as random events. In addition, Dr. Padgett conveniently ignores the effects of the plethora of other Part 15 devices, including the wide-area data distribution networks of Metricom and others, that are expected to occupy the band, which could very well be a bigger interference problem than a *fully loaded* wideband forward link *during peak busy hour*, let alone a wideband forward link under more typical operating conditions. Because none of these factors figured into Dr. Padgett's analysis, it is no more than an impressive statistical dynamic exercise.

Two copies of this letter are being filed as required by Section 1.1206(a)(1) of the Rules.

Respectfully submitted,

Louis H.M. Jandrell
Vice President Design & Development
Pinpoint Communications, Inc.

Attachments

cc: Attached list

ATTACHMENT

PROPOSED STEPS TO INCREASE COMPATIBILITY OF PART 15 DEVICES WITH WIDE-AREA AVM

Introduction

A few certain members of the Part 15 coalition have expressed concern about the wideband forward link in Pinpoint's ARRAY™ system. Specifically, they have been particularly fearful that Pinpoint will, in the future, elect to operate this link, not at the 500 W ERP levels currently used by Pinpoint, but at the much higher power levels actually permitted under the current rules and that might be allowed under revised rules. To provide comfort with respect to this concern expressed by the Part 15 community, Pinpoint would support a prohibition of operating AVM base stations above the 500 W ERP level. Regarding the operation of the wide band forward link apart from power levels, Pinpoint believes that the critics of this technique have overstated the interference potential of such links, particularly as it relates to Pinpoint's network design. The paragraphs below discussing base station transmit duty factors and the aggregation of a base station's transmissions are offered to help to clarify these issues. In conjunction with revised power limitations which we would support, Pinpoint hopes these operational constraints will resolve essentially all of the concerns that have been expressed with regard to the wide band forward link.

With these limits on maximum transmit power level, low maximum duty factors, energy density and short communication range, the potential for interference between unlicensed devices and the wideband forward link used by high-speed radiolocation systems will be very small. Where such interference does occasionally occur, Part 15 devices should be able to use robustness features already typically designed into them to ameliorate the effects of any such interference in order to accommodate the requirements of Section 15.5(b).

Considerations:

Some parties in PR Docket No. 93-61 have expressed a concern that the wideband forward link used in some of the high-speed AVM systems may cause severe and widespread interference to many low-powered Part 15 services now or soon to be in operation. To some degree, this fear results from simplistic path-loss propagation analyses based on the incorrect assumption that a wideband forward link means that all base stations within an AVM system would transmit at peak levels continuously and simultaneously. Some of these analyses have also assumed that AVM base stations employing a wideband forward link would operate at power levels much higher than are or will be used. Actual operating parameters of AVM systems that will use a wideband forward link are much different, requiring a radical reassessment of any expectations of interference from a wideband forward link.

For example, Pinpoint's system, designed for use under the interim AVM rules, functions in "half-duplex" fashion without simulcasting. Within a "frequency reuse area" (the area covered by about 30 base stations with approximately 5 to 10 mile spacing) only one base station will transmit polling or message or control signals at a time. Simultaneous transmissions within such an area would cause self-interference.

Because the entire AVM traffic load (both radio-location and related data) is carried by these 30 base stations, each base station, on average, carries only about 3% of the network's traffic load within the "frequency reuse area." For most of the location traffic, which represents the majority of the network's operational services, the average base station's transmission occupies the air for about 1/3 of time devoted to this traffic. Thus, ***on a fully loaded system functioning at 100% theoretical peak capacity,*** the typical base station, on average, ***transmits for less than 1% of the time.***

In actual operation, traffic on a *fully subscribed* system is likely to use only a small fraction of the 100% "theoretical" capacity. This apparent reduction is to allow for transient peak loading without causing significant increases of latency delay. Therefore, the *busiest* base station is likely to have an *average transmit duty factor of less than 3%*, even when the busiest base station carries 10 times the load of the average least busy base stations. Allowing further that transient peaks in message-radiolocation traffic are three times that of the average traffic, would still mean that the busiest station would be transmitting, transiently, with *peak duty factors* of less than 10%. We must reiterate that these values of airtime duty factors are based on "theoretical maximum" values, only practically achievable under "diagnostic" conditions and theoretical-maximum demand.

In reality, the values will be very much smaller than these maximum values, typically as much as 5 to 30 times less even for fully loaded systems, with transient traffic peaks only occasionally approaching these theoretical levels. Practical maximum "average" load levels are expected to grow over time, as various applications penetrate their markets and the number of subscribers increases.

To understand the real impact of the AVM network on airtime, it is important to understand latency. Transaction latency is a very important aspect of the ARRAY AVM system's service offering. Transaction latency is the delay between making a request for service and its being accomplished. (Why is it so important? There is little point in getting frequent or accurate updates of a police car's position if the reported position is that of thirty or more seconds ago, by which time the vehicle may be more than half a mile from the reported position). Therefore, it is a specific design requirement to provide "apparent excess capacity" so that the "bursty" nature of the transaction traffic does not force the response time during transient traffic peaks to be drawn out due to queuing. Pinpoint has allowed a factor of 3 for the peak-to-average ratio, meaning that when the network is handling its design maximum traffic, the average traffic will be less than a third of "theoretical maximum" of either vehicle location or message delivery, *i.e.* the maximum-average number of randomly addressed position fixes would be 500 per second out of a "theoretical peak maximum" of 1500 per second. The network will still, however, be transiently performing randomly addressed position fixes at up to 1500 per second when required!

Furthermore, it will take a number of years for the network traffic to build to these levels, just as the growth of the Part 15 device population will take time. The prediction, by Part 15 interests, of instantaneous, traumatic impact are very overstated.

Forward Link Proposals:

The above discussion demonstrates that when a Part 15 device operates in such close proximity to an AVM base station using a wideband forward link that a transmitting base station will cause interference, the likelihood of debilitating interference from that base is very small. To reduce that small chance even further (in addition to the power level limitation discussed in the *Introduction*) Pinpoint proposes the following restrictions on a wideband forward link:

1 The 918-926 MHz band should be shared among wide-area AVM systems capable of time-sharing, local-area AVM systems, and compatible Part 15 devices (*i.e.*, all Part 15 devices that do not disable wide-area AVM systems for more than some acceptable percentage of the time over more than some acceptable percentage of the AVM license area).

2 Resolution of interference situations between wide-area and local-area AVM systems will be through established procedures under the mutual cooperation mandates of Section 90.173(b) of the FCC Rules. The second operator would have the obligation to install its system in a manner that minimizes the potential for interference, but both operators in an interference dispute would have the obligation to seek and make modifications to their own systems to eliminate or reduce the harmful interference. Detailed additional procedures could be established by the FCC subject to notice and comment requirements.

3 All Part 15 operations will still be subject to the current hierarchy rules. Part 15.5, like Section 90.173(b), could be augmented by a more definitive dispute resolution process or etiquette, rather than the current rules, for instances of interference between wide-area AVM systems and unlicensed devices.

4 Steps should be taken to keep the potential for interference from wideband forward links to Part 15 devices to a minimum. Some ways of doing this are:

- Ensure that the transmit energy per unit bandwidth of a wideband forward link is low. Accordingly, Pinpoint reiterates that it is willing to accept a base station power limitation of 500 W ERP.

- Ensure that the time-probability of collision between a wideband forward link and a Part 15 device is small.

Regarding the first bullet above, it should be noted that the spectral energy density of the Pinpoint system's forward link currently is designed (at 500 W ERP) to operate with an energy density similar to that of a Part 15 frequency-hopping spread spectrum system operating at 4 W EIRP

Pinpoint's ARRAY™ system is fully capable of satisfying the second bullet as well. With the few simple duty-factor restrictions on the licensed service illustrated below, the quality of access to the shared spectrum would be very much higher for both the licensed and unlicensed users of the band. In addition, the time and spatial diversity characteristics of their respective operations would allow both systems significantly better access to the whole available band than if the band were narrowly frequency-partitioned in "dedicated fashion" for each individual user or group of users. At a small compromise in cost and operational complexity, wide-area AVM and wide-area high-powered Part 15 users alike could gain very significantly greater quality and capacity from the band.

While the actual expected average and peak duty factors expected from any particular AVM system using a wideband forward link would typically be much lower than the limits suggested below, the values offered below indicate the levels we feel are of the right magnitude for generally applicable regulations. Such values would reserve system flexibility for system designers planning new or different systems without undermining compatibility with Part 15.

The duty-factor limitations could take the following form:

(1) Any particular licensed base station shall keep its duty factor below a certain percentage (3% average and 10% peak), where duty factor is defined as (total transmit time in any 100 second integrating interval)/(100 seconds);

(2) Any local group of base stations (defined as any base station and the six base stations closest to it) shall keep its cumulative duty factor below another, somewhat higher, percentage (10% average and 30% peak);

(3) The transmission patterns of individual base stations shall consist of tightly-bunched groups of transaction "bursts," interspersed by much longer inactive periods of at least some minimum limit (300 milliseconds). See Figure 1 below; and

(4) The maximum "silent-gap" between transmissions within each such "burst" shall not be greater than 1 millisecond. Figure 1 illustrates the "bunching" notion and its implementation.

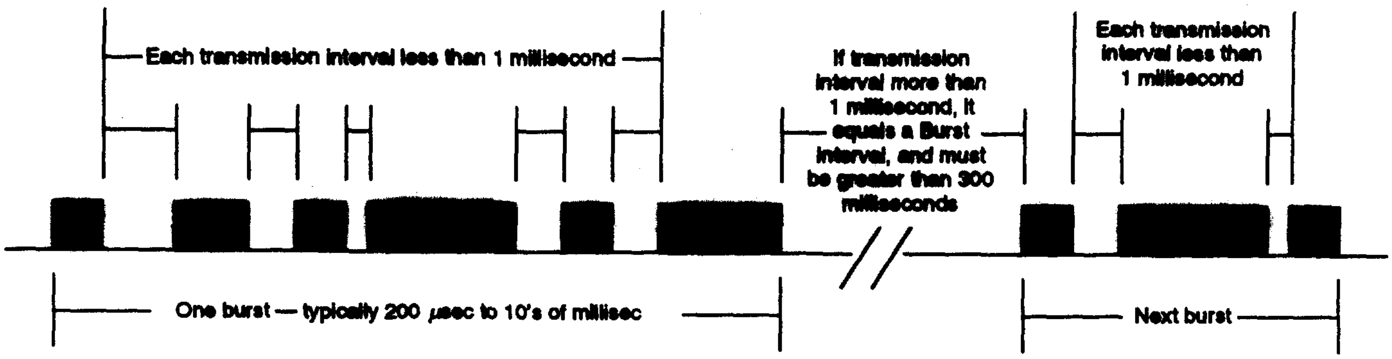

FIGURE 1: Definition and Requirement of Burst Interval (Pulse durations and intervals not to scale)

It is clear that the respective performance of each of the shared operations will critically depend on the values of the specific limits, but the examples clearly show the possibilities that exist for each of the services sharing the band.

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